UNIVERSITY OF CALIFORNIA—COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

E. W. HILGARD, Director.

TOLERANCE OF ALKALI BY VARIOUS CULTURES

By R. H. LOUGHRIDGE.

BRANCH OF "ALKALIED" PEAR TREE.

BULLETIN No. 133.

(Berkeley, August, 1901.)

SACRAMENTO:

A. J. JOHNSTON, : : : : : SUPERINTENDENT STATE PRINTING.

1901.

EXPERIMENT STATION STAFF.

E. W. HILGARD, Ph.D., LL.D., *Director and Chemist.*
E. J. WICKSON, M.A., *Horticulturist and Superintendent of Agricultural Ground .*
R. H. LOUGHRIDGE, Ph.D., *Agricultural Geologist and Chemist.*
C. W. WOODWORTH, M.S., *Entomologist.*
W. A. SETCHELL, Ph.D., *Botanist.*
M. E. JAFFA, M.S., *First Assistant Chemist, Agricultural Laboratory.*
GEORGE E. COLBY, M.S., *Second Assistant Chemist, Agricultural Laboratory.*
FREDERIC T. BIOLETTI, B.S., *Bacteriologist and Foreman of Viticultural Cellar.*
J. BURTT DAVY, *Assistant Botanist.*
LEROY ANDERSON, M.S.A., *Dairy Husbandman.*
A. R. WARD, B.S.A., D.V.M., *Veterinarian.*
E. H. TWIGHT, *Assistant in Viticulture.*
CHARLES H. SHINN, A.B., *Inspector of Stations.*
C. A. COLMORE, *Clerk to Director.*
EMIL KELLNER, *Foreman of Central Station Grounds.*

JOHN TUOHY, *Patron,*
JULIUS FORRER, *Foreman,* } Tulare Substation, Tulare.

R. C. RUST, *Patron,*
JOHN H. BARBER, *Foreman,* } Foothill Substation, Jackson.

S. D. MERK, *Patron,*
J. W. NEAL, } Coast Range Substation, Paso Robles.

S. N. ANDROUS, *Patron,*
J. W. MILLS, *Foreman,* } Southern California Substation, { Pomona. / Ontario.

V. C. RICHARDS, *Patron,*
T. L. BOHLENDER, *in charge,* } Forestry Station, Chico.

ROY JONES, *Patron,*
WM. SHUTT, *Foreman,* } Forestry Station, Santa Monica.

TABLE OF CONTENTS.

Page.

WORK DONE HERETOFORE 5
UTILIZATION OF ALKALI LANDS 6
FIELD OF OBSERVATION 7
INJURIOUS NATURE OF COMMON SALT 9
EXTENT OF INVESTIGATIONS 10
DIFFICULTIES IN INTERPRETATION OF RESULTS 10
RESULTS OF OBSERVATIONS 12
ORCHARD TREES 12
Table of analyses of alkali soils 12
Almonds, Apples, Apricots 12–14
Figs, Mulberry, Lemons, Oranges 14–18
Olives, Peaches, Pears 18–19
Plums, Prunes, Walnuts 20
VINEYARD 21
Table of analyses of alkali soils 21
Note on the effect of alkali on growth of vines and composition of grapes; A. M. dal Piaz 23
GRAIN 24
Table of analyses of alkali soils 25
Wheat, Gluten Wheat, Barley, Rye 25–27
LEGUMES AND FODDER PLANTS 27
Table of analyses of alkali soils 27
Alfalfa 28
Blue European Lupin, Hairy Vetch 30
Bur Clover, Australian and Argentine Saltbushes 31–32
Sorghum, White Melilot 32–33
Goat's Rue, Jersey Kale, Essex Rape 33
Modiola 33
VEGETABLES 33
Table of analyses of alkali soils 34
Sugar Beets 34
Carrots, Radishes, Artichokes 35–36
Spinach, English Broad Bean 36
Spelt, Eleusine, Celery 36
Onions, Potatoes 36
GRASSES 36
Ray and other grasses 36

RESULTS OF OBSERVATIONS—CONTINUED.

Page.
MISCELLANEOUS 37
Table of analyses of alkali soils 37
Russian Sunflower 38
Washingtonia Palms 38
Date Palms, Camphor Tree 38
Oriental Sycamore 38
Eucalyptus, Kölreuteria 38
GENERAL SUMMARY OF RESULTS 38
Tables showing highest amounts of alkali salts in which fruit trees and smaller cultures grow 39
ADDITIONAL DATA ON CULTURES IN ALKALI AT THE SOUTHERN CALIFORNIA SUBSTATION 40
CONCLUSIONS 41

TOLERANCE OF ALKALI BY VARIOUS CULTURES.

By R. H. LOUGHRIDGE.

Alkali studies at this Station have thus far been chiefly directed toward the occurrence, character, and reclamation of alkali lands in California, the chief salt of which was carbonate of soda, the basis of black alkali; and several bulletins and reports on the subject have been printed and distributed very generally by the Station. Among these Bulletin No. 128, issued within the past year, is very full and comprehensive and can be had by application to the Station.

A few observations have been made with reference to the power of certain cereal and fodder crops to withstand the effects of alkali, and the results are given in the Annual Report of 1896. But as a rule the amounts were ascertained for a depth of one foot only, because at the Chino substation the greater part of the salts was held within that depth, and the majority of the cultures observed had shallow root-systems. The results have not, therefore, that value which would have been reached by deeper examination of the soils.

In the past two years, however, we have extended the investigations and have endeavored to ascertain, as far as possible, the highest amount of each salt occurring in four feet depth in which the different cultures of all kinds—orchard, as well as others—will grow and come to maturity; for while it is true that it is the alkali within the first foot or two of the surface that is liable to produce the chief injury upon the roots of the plants, it is certain that there will come a time in the cultivation of the land when nearly all of the salts that lie in the lower depths of the soil will be reached and dissolved by the water that has been given to the soil either by rainfall or by irrigation in sufficient amounts to percolate downward to it, and will be brought up and concentrated at or near the surface. This has occurred in the substations at Tulare and Chino.

It is this concentration that has proved so destructive to many cultures that for a time have done well; and it is this total amount within reach of water that must be considered when orchard trees or perennial crops are planted, if the farmer wishes to avoid the agony of seeing his work and hopes of years swept away by the sudden activity of an enemy which has been hidden in the lower depths of his land.

All of this injury to cultures was at first naturally attributed either to the content of carbonate of soda in the surface foot, where its corrosive action on the tender bark of the root crown could be felt, or to the very

large amount of total salts which might produce stagnation of the sap or other injury to the feeding rootlets. Some analyses and observations were made at that time both on the amounts of alkali which caused suffering, and on the amounts in soils where no trouble appeared; the results are given in previous reports.

The depth of four feet has been adopted as the proper one, because investigations in the San Joaquin Valley and in the valley of Southern California have shown that in all but the sandiest of soils the substrata below that depth, while not entirely free from alkali salts, contain so little and are so commonly beyond the depth to which rainfall or irrigation water penetrates or the effect of subsequent surface evaporation is felt, that the consideration of their content of alkali is unimportant.

Utilization of Alkali Lands.—The proper utilization of alkali lands implies a due regard on the part of the farmer to the several conditions accompanying the alkali deposit, each of which has its influence upon the method of treatment to be pursued in the reclamation of the land, in the selection of suitable crops, and in their cultivation and irrigation. These conditions are, *first*, the *nature* of the alkali salts, whether chiefly carbonate (black alkali), sulfates, or chlorids (common salt); *second*, the *position* of the alkali in the soil-column, whether near the surface or several feet below; and, *third*, the *amount* of these salts contained within reach of the plant, or which would at some time rise to the surface. These several conditions have repeatedly been treated of in the several Station publications on the subject of alkali, but it seems to be important that they be briefly given again here.

The examination of the soil to a depth of five or six feet in localities where alkali either is known or is suspected to exist is of course the first thing of importance, and an average sample of each foot in depth should be taken; the result of the chemical examination of these will clearly indicate the conditions to be met.

First, with regard to the nature of the salts: Carbonate of soda (black alkali), if present, may be neutralized by the application of gypsum in an amount exceeding that of the carbonate present; rainfall or irrigation water will dissolve this, and as rapidly as the solution comes in contact with the carbonate the latter will be converted into the far less harmful sulfate or glauber salt. This will, of course, increase the amount of the sulfate, and if then this salt is too great for the tolerance of plants it must be removed by drainage, or driven deeply into the lower depths of the soil by copious irrigation. Common salt and the sulfates ("white alkali") can be successfully treated only by removal from the soil limits of five or six feet depth. Nothing can be applied that will render them harmless when they are present in amounts exceeding the tolerance of crops. This removal from the soil may be done either by underdrains of tiles at a depth of four feet, the alkali drainage-water being conducted

into a stream, or into a well dug for the purpose to underlying gravel, or, as has been done at the Tulare substation, into a natural sump; or by deep ditches into which the alkali-charged water may enter by seepage from flooded areas. Alkali is quickly soluble in water and rapidly percolates downward into the soil if the latter is at all leachy, and it would be practically impossible to wash it off of the soil by flooding and shallow surface drains. A surface inch of water soaks to about six or eight inches depth in a sandy soil, and to four inches in one more clayey.

Second, the position in the soil-column: Where the alkali is at the surface suitable means toward reclamation or removal must be adopted as indicated above, or the alkali must be made to sink to a depth of several feet and kept there out of the reach of the tender plant-roots; or crops must be chosen suitable for the character and strength of the alkali.

On the other hand, where the alkali is *not* at the surface, either such shallow-rooted crops should be planted whose roots will remain above the alkali zone, and such cultivation and irrigation be given that the mass of alkali at several feet depth is not disturbed, or the alkali must be driven deeper into the soil and kept there; or such crops should be selected as may be able to tolerate the amount of alkali occurring in the entire soil, whether that alkali be subsequently concentrated near the surface or distributed throughout the three or four feet. The roots of deep-rooted crops and trees may be able to remain in the upper soil for awhile, but they soon grow downward to the vicinity of the alkali and are affected.

Third, a careful selection of such cultures should be made as are known to withstand the amount and nature of alkali present. For instance, the apple is apparently severely injured by the presence of 3,000 pounds of common salt per acre in four feet; while the olive grows well at Tulare in a soil containing as much as 5,600 pounds of that salt per acre. While, therefore, olives would grow where apples died, it would be folly to attempt to raise apples on land with so large an amount of alkali simply because olives do well on it.

It is the hope of the Station to be able thus to ascertain the maximum or safe tolerance of the various cultures, either large or small, for either carbonate of soda, common salt, or the sulfate; so as to enable farmers to choose for such lands only those cultures that will probably succeed. It is thought that much alkali land might be put to profitable cultivation that now lies idle because, having proved incompatible to some one crop, it has been thought to be unsuitable for all.

Field of Observation.—The Tulare and Chino substations have thus far been almost the only fields of observation, while experiments on reclamation problems have been conducted at the former station at the same time.

The Tulare tract was originally chosen for the purpose of making its alkali land the subject of special study and investigation; and at that time but one large alkali spot was in sight on the surface, the rest being covered with native grasses and wildflowers. Alkali hardpan, however, did exist at depths of from twelve to thirty-six inches, and the necessary use of irrigation water has, by percolation to the alkali and subsequent capillary rise, brought the dissolved salts to the surface here and there over the tract, and produced a number of gradually enlarging alkali spots. This gave a larger field of reclamation work than had been intended at first, while at the same time enlarging the scope of observation on various cultures. The effect of this rise of alkali was seen in the

PLATE 1. WHEAT GROWING 3 FEET HIGH IN SOIL CRUSTED WITH WHITE ALKALI, ORIGINALLY A BARREN BLACK-ALKALI SPOT. TULARE EXPERIMENT SUBSTATION.

blighted appearance of tree growths and other cultures that had at first been doing well, as well as in the bare spots so characteristic of "black alkali."

Reclamation of the black alkali has been carried on for a number of years, gypsum being applied, turned under and thoroughly watered. The result has been a very general conversion of the dreaded carbonate of soda into the far less harmful sulfate; and on spots where not a blade of grass would previously grow, there have been produced excellent wheat and barley, three or four feet high and full-headed, although the surface of the ground was at harvest time covered by a thick crust of white alkali. (See plate 1.) Photographic illustrations of this growth have been given in the Annual Report of the Station for 1897–8, and in Bulletin No. 128.

Experiments have also been made with respect to the removal of the

alkali by underdrainage, through tiles, into a deep well; and also by carting away from spots where the alkali had, by deep percolation of irrigating water and subsequent rise by evaporation from the surface, been purposely made to come to the surface. Both methods were quite successful and large amounts of salts were thus removed from some of the alkali spots.

These are the only methods by which common salt and the sulfates can be removed from lands charged with them.

Injurious Nature of Common Salt.—The neutralization of the corrosive carbonate of soda in the alkali soils of Tulare by means of gypsum led to the belief that the various growths in orchard and vineyard and the smaller cultures would show very material improvement, but such anticipations have been but partially realized. It is true that the land was largely reclaimed from the evils of the carbonate of soda (black alkali), and that some of the cultures, such as wheat and barley, were enabled to grow and produce excellent crops, but other crops and trees still suffered from the effects of so-called *white alkali* (chlorid and sulfate of sodium, or common and glauber salt), from which the land had not been freed. Apple trees, for instance, were severely "alkalied," as partly shown in the photograph on page 13 (plate 2).

The injurious nature of *common salt* to plants in sea-coast lands has long been known, and has been largely attributed to the *bittern* (magnesium chlorid) that it contains; but the investigations at Tulare show that common salt in itself is highly injurious to plant growth. Its chief action seems to be that of an antiseptic which arrests development, or kills the nitrifying organisms in the soil.

It was therefore determined to make a detailed examination of the soils in which the various important cultures grew, and thus to ascertain the alkali conditions and the cause of suffering, and at the same time to make a study of the tolerance of the several salts on the part of the orchard trees. For this purpose the writer visited the Tulare substation in the summer of 1900, and, with the Inspector of Stations and the Foreman, selected trees and other cultures that were clearly suffering from alkali and those of the same variety that were doing well. Average samples of the soil of each foot to a depth of four feet were taken at a distance of about three feet from the tree, and from nearer other cultures. Photographs were also made. The results of the analyses of these soil-samples are of special interest in throwing new light on the tolerance of alkali by plants, and especially in that they bring forward prominently the evil effects of common salt, an enemy to crop production almost if not fully as dangerous as black alkali itself, though acting in a different manner. Heretofore its influence has been in a large measure overlooked, because of the reputation and prominence of carbonate of soda as an agent of destruction; and had not the land of the substation

been so generally freed from the latter by the use of gypsum, the full power of mischief of common salt upon plant and tree growth would, perhaps, not have been brought out so well as in this investigation.

The fact that lands charged with carbonate of soda may be reclaimed from that particular salt by the use of gypsum makes the study of tolerance of the other ingredients of great importance; for if the soil, for instance, contained, in addition to the carbonate of soda, an amount of *common salt* that would in itself prove highly injurious to plant life, and which could not be leached out of the land by drainage, then the expense of the gypsum application to reclaim the black alkali would be useless; or if the conversion of the carbonate into the sulfate of soda by gypsum increases that already present to an extent approaching an amount not tolerated by plants, and no means of leaching and underdrainage exists, then the work of reclamation would also be useless. These points should all be considered by the farmer before gypsum is bought and reclamation of his land is begun.

Extent of the Investigation.—About one hundred varieties of cultures have been studied; these embrace orchard trees, grain and forage crops, grasses, vegetables, and other miscellaneous growths. The greater part of the results are valuable toward reaching the end in view, but others were disappointing in that the soils showed a far less amount of alkali salts than was indicated by surrounding conditions.

In many cases, several localities were chosen for the examination of the soil of the same culture, for it is impossible to judge of the nature and extent of alkali soils by the eye alone. For instance, many alfalfa fields in several parts of the State were sampled before conclusions at all satisfactory were reached, the majority having less than we had reason to believe.

The samples have all been carefully taken, each foot of the vertical soil-column being carefully mixed, in order that its sample may be an average of that foot. Many hundred analyses have been made with the assistance of Messrs. Colby, Snow, Lea, and Werthmueller.

A quick and at the same time accurate method of extracting the alkali from the soil has been adopted; instead of placing the dry soil on a filter and washing all of the alkali out with water, which often required two or more weeks in clay soils because of puddling by the carbonate of soda, a weighed amount is mixed with a measured quantity of water and allowed to digest for twenty-four hours with frequent shaking. The salts thus dissolved are thoroughly diffused through the liquid, and an aliquot part may be taken for evaporation and examination. If necessary, a portion may be passed through a filter to clear it from sediment, but very often the solution settles perfectly clear.

Difficulties in Interpretation of Results.—There are a number of conditions which may affect the interpretation of the results of alkali

examinations and lead to erroneous conclusions with regard to the effect of alkali on cultures. These are climatic conditions, the possible presence of insects or diseases, imperfect physical conditions in the soil and subsoil, such as hardpan, high water-table, shallowness of the soil, lack of ventilation and aëration, poor moisture supply, etc., any of which might cause intense suffering on the part of the plant. All of these must be considered before alkali can be charged with the trouble. Then when we come to consider the alkali itself we are met by its complexity and variability in composition, and it is only by a process of elimination that definite conclusions can be reached. It is easy enough to make tables showing the highest amount of each salt thus far found to be tolerated by the different cultures, but it is often very difficult to say positively that the death or suffering on the part of a culture is due to the presence of a certain salt, for other salts are always present in large or small amounts. When, however, the amount of one of the constituents is far below, and that of another is much above the amount tolerated by the plant elsewhere, it is quite safe to conclude that any distress on the part of the plant is due to the latter; provided, of course, that physical conditions of the soil are favorable to the life of the plant. In some cases where the amount of a certain salt was enormous, there could be but little doubt that the suffering of the plant was due to it; but the *lowest* limit of such intolerance is as yet undetermined.

The following tables give some of the results obtained by the analysis of the alkali soils bearing various crops, the effort being to select such as were typical of the effect and non-effect of alkali upon the growth. While the samples were actually examined for each foot in depth, it has been thought best for this bulletin to give only the average of the entire column as a whole, especially for the orchard trees whose roots penetrate deeply into the soil when free to do so. For smaller cultures, whose roots are chiefly found in the upper two feet of the soil, we give results for each of the two feet and the total found in four feet; otherwise the results would prove very puzzling and conflicting. The results are briefly discussed for each culture and a comparative summary of maximum tolerance is given in tabular form at the end of the bulletin.

We do not present all of the soils whose examinations have been made, but only those of most importance in showing the maximum of tolerance for the various crops; as already stated, many alkali spots were examined that gave no definite results, and are therefore omitted from the statement.

It should be said that the limits of tolerance thus far shown are probably for the most part too low, and that further investigation will without doubt greatly enlarge these limits on the part of some of the crops enumerated. We propose to continue the work, and with the aid of farmers living in alkali regions we hope to greatly add to the number and value of observations already made.

RESULTS OF INVESTIGATION.

ORCHARD TREES.

Analyses of orchard soils have been made from a number of localities, but those given in the tables are mostly from the Tulare substation. It will be seen that the list comprises the chief orchard crops of California; and while most of them are represented in their extremes of good and poor growths, there are a few which could only be found in a state of good growth, and in what seemed to be strong alkali.

Alkali in Soils of Orchards.

Trees.	Condition	Per Cent in Soil.				Pounds per Acre; 4 ft. depth.			
		Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda).	Chlorid (Common Salt)	Total Alkali
ALMONDS—									
Tulare	Good	.142	.009	.015	.166	22,720	1,440	2,400	26,560
APPLES—									
Tulare—Red Bietigheimer	Good	.089	.004	.008	.101	14,240	640	1,240	16,120
Duchess	Poor	.117	.008	.021	.146	18,760	1,200	3,320	23,280
Jonathan	Poor	.029	.005	.007	.041	6,840	1,080	1,720	9,640
APRICOTS—									
Tulare	Good	.054	.003	.006	.063	8,640	480	960	10,080
Tulare	Affected	.214	.011	.021	.246	34,240	1,760	3,260	39,260
FIGS—									
Tulare—Osburn's Prolific	Good	.153	.007	.005	.165	24,480	1,120	800	26,400
California Black	Good	.068	.005	.001	.074	10,880	760	160	11,800
LEMONS—									
La Mirada	Good	.028	.003	.005	.036	4,480	480	800	5,760
La Mirada	Stunted	.032	.003	.009	.044	5,120	480	1,440	7,040
La Mirada	Dead	.039	.007	.012	.058	6,240	1,120	1,920	9,280
OLIVES—									
Tulare—Nigerina	Good	.192	.018	.042	.252	30,640	2,880	6,640	40,160
Regalis	Good	.126	.017	.021	.164	20,160	2,640	3,360	26,160
La Mirada	Good	.025	.015	.014	.054	4,000	2,400	2,240	8,640
La Mirada	Stunted	.271	.029	.074	.374	43,360	4,640	11,840	59,840
Kern City 5 feet	Dead	.245	.010	.152	.407	49,000	2,000	30,400	81,400
ORANGES—									
Tulare	Fair	.062	.024	.021	.107	9,840	3,840	3,360	17,040
Chino	Good	.155	.012	.015	.182	18,600	1,440	1,800	21,840
Corona	Fair	.018	.008	.002	.028	2,920	1,280	360	4,560
Corona	Poor	.028	.013	.011	.052	4,520	2,000	1,800	8,320
Corona	Poor	.029	.010	.015	.054	4,720	1,680	2,520	8,920
PEACHES—									
Tulare	Best	.060	.004	.006	.070	9,600	680	1,000	11,280
Tulare	Poor	.084	.007	.015	.106	13,400	1,160	2,440	17,000
Hanford	Poor	.088	.002	.070	.160	14,080	320	11,200	25,600
PEARS—									
Tulare	Best	.111	.011	.009	.131	17,800	1,760	1,360	20,920
Tulare	Poor	.239	.013	.009	.261	38,280	2,080	1,360	41,720
PLUMS—									
Tulare	Very poor	.140	.011	.014	.165	22,360	1,760	2,120	26,240
PRUNES ON MYROBALAN—									
Tulare	Good	.058	.009	.008	.075	9,240	1,360	1,200	11,800
MULBERRY—									
Tulare	Good	.021	.001	.014	.036	3,360	160	2,240	5,760

Almonds.—The almond trees of the Tulare substation are isolated from the other orchard growths and were all in a healthy condition and

Red Bietigheimer. Duchess of Oldenburg. Jonathan.

PLATE 2. APPLE TREES.

loaded with fruit at the time visited. The varieties were the I X L and Harriott's Seedling. The soil samples were taken from midway between the trees to a depth of four feet. No trees have been found whose poor condition could be attributed to alkali; hence, the greatest limit of tolerance in the almond has as yet not been ascertained, but is clearly above 2,000 pounds of carbonate of soda and 3,000 pounds of common salt per acre four feet deep.

Apples.—The only observations made on the apple were at the Tulare substation in 1900. The tree is quite sensitive to alkali salts, and their effect on the foliage of the tree was very marked, as is shown in the accompanying illustration (plate 2) from a photograph made at the time the soil samples were taken. The newer limbs of the tree appear as canes with a tuft of leaves at the upper end, instead of being covered with foliage throughout, as is also shown in the photograph. Samples of soil were taken to the depth of four feet under the Duchess of Oldenburg, which was in very poor condition, with no fruit, and whose top was losing its leaves; the Jonathan, also very poor, and the Red Bietigheimer, which was in excellent condition. The results of the examination make it clear that while the apple will tolerate the presence of 14,000 pounds of sulfates, 650 of carbonate of soda, and 1,200 of common salt, it is injured by 1,200 pounds of carbonate and 3,000 pounds of common salt per acre distributed through four feet depth. The Jonathan seems to be more sensitive than the Duchess.

Apricots.—The trees selected as representing the best and the worst condition respectively were grown upon their own stock. The differences between the two were very marked, in the greater height and full foliage, large leaves, and vigorous growth in the one, and the thinner foliage, smaller and blighted leaves, new leaves in clusters at end of limb, and evident poor health in the other; some twigs had lost their leaves entirely. The accompanying photograph (plate 3) shows these effects. The results of the examination of the respective soils show that while the total alkali and that of each salt are greater in the soil of the poor tree, and that to either of these might be attributed the trouble, it is more than likely that either the sulfate or the common salt is the true cause; for their amounts are excessive, while that of the carbonate is lower than what is tolerated by most cultures.

Figs.—The examinations for fig trees gave results that were not of special importance, for the amounts of common salt and carbonate of soda present in the soil were not very large. The tree easily tolerated as much as 25,000 pounds of glauber salt and 1,100 pounds of carbonate of soda per acre in four feet.

Lemons.—The lemon seems to be the least tolerant of all of the fruit trees, for it was stunted by only 1,440 pounds of common salt per acre

Good.

Yielding to alkali.

PLATE 3. APRICOT TREES.

distributed through four feet depth, and was killed by 1,900 pounds combined with 1,900 pounds of carbonate of soda. Its endurance of carbonate of soda has not been ascertained. The trees examined were from an orchard near La Mirada, Los Angeles County. In one part of the tract the trees were doing well, the soil showing only comparatively small amounts of alkali salts. In another the trees were stunted, and an examination showed no signs of disease, the trouble being evidently due to the alkali. In the lower part of the orchard, at the end of the irrigation furrow, where water was caught from run-off during the past five or six years, thus permitting the alkali to accumulate, the trees

PLATE 4. LEMON ORCHARD AFFECTED BY ALKALI; BEFORE DEEP IRRIGATION.

have during the past year showed signs of disease, and many have died. The alkali in this land is much in excess of that where the trees were merely stunted, thus indicating this excess as the cause of trouble.

The manager of the orchard, Mr. S., told the writer that he had by a system of subirrigation caused water to dissolve the salt and carry it deeply into the ground out of reach of the feeding roots of the trees, its rise to the surface being prevented by cultivation of the soil. The result appeared in the greatly improved condition of the trees, which in eight or ten months after this treatment seem to have almost recovered their vigor. Photographs of the trees before (plate 4) and after (plate 5) treatment were taken by Mrs. S., and are reproduced in the accompanying engravings.

Oranges.—From the culture experiments at Tulare substation it would seem that oranges do fairly well in the presence of 3,840 pounds of carbonate and 3,360 pounds of common salt per acre in four feet depth, or a total of 17,040 pounds of alkali. The examinations at Corona seem to contradict this, for there the trees suffered in 1,680 pounds of carbonate and 2,500 pounds of common salt. The explanation is that the conditions surrounding the trees were different, for at Tulare a detailed examination shows that the salts were distributed through the four feet of soil quite evenly, while at Corona the common salt was all contained in the first two feet. Then, too, at Tulare the

PLATE 5. THE ABOVE ORCHARD AFTER ALKALI WAS DRIVEN DOWN BY DEEP IRRIGATION, FOLLOWED BY CULTIVATION.

roots of the tree were by proper culture encouraged to send their feeding roots to a depth of seven or eight feet below the surface, while at Corona the system of shallow furrow-irrigation so much practiced in Southern California had compelled the roots to remain within a short distance of the surface of the soil to secure necessary moisture, and hence the salt concentrated near the surface could act with greater energy.

Thus is emphasized the importance of the oft-repeated injunction to so use irrigation water and cultivation as to permit the roots of trees to follow their natural tendency of penetrating deeply into the soil. Had the salts in the Corona soils been distributed through a greater depth

the trees would doubtless have withstood the effects of the alkali much longer. In fact, since the publication of the Station Report of 1898, the orchardists of Corona have very greatly improved their groves by this treatment and the use of pure water; and the particular orchard there shown as typical of the effects of alkali has now recovered its vigor and foliage.

Mulberry.—The extreme tolerance of the mulberry could not be ascertained, as the few trees were all in excellent condition with no more of common salt or of other salts than is tolerated by other trees.

Olives.—The olive trees of the Tulare substation were all in good condition when visited, though some stood in soils quite highly charged with alkali salts. Of those represented in the table the Præcox was in a sandy soil, while the Regalis and Nigerina were in loams. Samples of soil were also sent to this office from an olive orchard near La Mirada, Los Angeles County, by the manager. One lot of samples was from the high part of the orchard, where the trees were large and healthy; the other lot was from lower land, where the trees were six years old, but stunted (four feet high); the same treatment had been given the trees in both cases. Another series of samples were sent by the manager of an olive orchard near Kern City, Kern County, in which the trees were suffering. The results of examination are shown in the table.

The olive tree is clearly immune to as much as 3,000 pounds of carbonate of soda (black alkali) and 30,000 pounds of glauber salt per acre in four feet, and the limit of tolerance will probably be found to be much above those figures.

The tolerance for common salt is above 6,000 pounds per acre in four feet, for the Nigerina did well in about that amount. At La Mirada the trees were stunted in presence of 11,800 pounds, and killed in an orchard near Kern City where there was 19,500 pounds in four feet depth and 30,400 pounds in five feet. At Kern City, however, the greater part of the alkali was contained in the soil below a depth of two feet, and had the examination gone deeper than five feet there would doubtless have been found in all about 50,000 pounds of common salt in a total of over 100,000 of alkali salts.

The following method of planting the trees adopted by the owner of the latter orchard has enabled them to secure a good growth before the roots felt the effects of the alkali, and illustrates the importance with some cultures of forcing the alkali down to quite a depth by the use of plenty of water and allowing the plant to secure a foothold:

The holes for the trees are made three feet deep and as wide, several months before planting; near planting time they are partially filled with good soil and filled with water. When the water has seeped down, the holes are filled with top soil and the trees planted. The alkali is thus

washed beyond the depth of the roots. There is hardly a doubt but that if there had not been such an enormous amount of alkali in the lower four or five feet the trees would have successfully resisted its effect on the roots.

Peaches.—The trees at the Tulare substation were in part in fairly good and in part in poor condition, and samples of soils were taken from the best representatives of each. Both were on peach stock, and the difference in appearance was in smaller leaves and general unhealthy growth, due to either the common salt or carbonate as shown in the table.

From the region of Hanford, Kings County, peach trees were reported as being in bad condition; and through the kindness of Mr. Motheral, samples were sent us for examination. "Many of the trees in this orchard are troubled with the supposed disease known as 'little peaches,' but in this particular place the trees had been cut back and were putting out new growth which was yellowish in color, evidently due to some trouble in the soil. The water level is usually at a depth of four or five feet below the surface, though after heavy rains it often rises to within three feet. The land of the region is naturally highly productive, and the trouble can only come from the effect of the water on the roots, or from alkali in the soil." The examination of this soil shows the presence of an enormous amount (11,200 pounds) of common salt in the four feet, to which doubtless the dying of the trees must be attributed.

The results obtained at Tulare make it probable that the limits of alkali tolerated by peach trees may be placed at 10,000 pounds of sulfates, 750 of carbonate, and 1,200 of common salt per acre in four feet depth.

Pears.—The effect of alkali upon the pear was noticed only in the orchard of the Tulare substation, where quite a large block of land is given to its culture. Through the central part of this lies a belt of alkali which has seriously injured some of the trees, the leaves turning yellow or blackening at the tips as shown in the photograph on the title-page of this bulletin, and others being killed. On either side of this belt the trees are in good condition and bear well. Samples of soil were taken under LeConte and Keiffer trees which were yielding to alkali, showing the yellow leaves with blackened tips; they had no fruit.

The samples from the "best trees" are from the northern part of the pear block. The trees are Kennedy varieties and were planted long before the alkali had encroached on them; so that their roots have escaped attack, although the amount of alkali is greater than under the other trees.

The results would seem to show that while the pear can tolerate as much as 1,400 pounds of common salt and 1,800 pounds of carbonate per acre in four feet, it is seriously affected by 38,000 pounds of the

sulfate, for it is hardly possible that an addition of 320 pounds of carbonate in the four feet per acre would produce the damage.

In another locality the trees were killed in land whose surface soil contained 4,600 pounds of carbonate and 18,000 pounds of common salt in a total of 62,000 pounds.

Plum on plum stock.

Prune on Myrobalan stock.

PLATE 6. PRUNE AND PLUM.

Plums.—The Robe de Sergent plum at the Tulare substation is on its own stock and suffering very severely from alkali, as shown in the photograph on plate 6. The tree was dwarfed, and the limbs were losing their leaves. The amount of alkali in this case was not large, only 26,240 pounds, and amounts of the carbonate and common salt were also

comparatively small. This plum, therefore, is one of the most sensitive of trees to the effects of alkali salts.

Prunes.—Prune trees, if grown on Myrobalan stock, should be highly tolerant of alkali salts, for that stock is a native of Asia Minor, where alkali abounds. We have thus far been unable to secure samples of soil where the trees showed the effect of alkali. At the Tulare substation the amount in their soils was only about 12,000 pounds per acre in four feet, and of this only 1,360 was of carbonate and 1,200 of common salt. It is said that at Hanford, Kings County, the prune flourishes in alkali soils where the peach is severely affected; we may therefore place the power of tolerance at quite high figures for common salt at least. If it be true that this fruit tree can withstand a very large amount of common salt it will prove of great value in alkali regions, for the carbonate of soda part of alkali can easily be neutralized by gypsum.

Walnuts.—Samples of soil were sent from an orchard near Anaheim, Orange County, in which "walnut trees have been planted, but they soon died and the roots rotted very quickly, while outside of this spot they do exceptionally well." The examination of the samples showed the presence of 18,000 pounds of common salt and about the same amount of sulfates per acre in four feet depth.

VINEYARDS.

A large part of the Tulare substation tract is occupied by grapes representing about one hundred and fifty varieties. Alkali spots have appeared here and there (by rise from below through use of irrigation water), and in several instances the salts have seriously affected the vines. The results of the examination of the soils forcibly illustrate the fact that the susceptibility of the vine varies according to variety, and that while some are tolerant of very large amounts of carbonate of soda and common salt, others succumb to the effect of far less of each.

Alkali in Vineyard Soils.

Grapevines.	Condition	Per Cent in Soil.				Pounds per Acre: 4 ft. depth.			
		Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda)	Chlorid (Common Salt)	Total Salts
Persian	Lived	.144	.063	.077	.284	17,290	7,550	9,640	34,480
Persian	Barely lived	.072	.214	.005	.291	8,670	25,620	640	34,930
Persian	Died	.205	.311	.091	.607	24,640	37,280	10,890	72,810
Sauvignon vert	Thrifty	.255	.003	.028	.286	40,800	480	4,480	45,760
Chasselas	Thrifty	.247	.005	.031	.283	39,520	800	4,960	45,280
Boal de Madeira	Thrifty	.188	.004	.028	.220	30,080	640	3,680	34,400
Mission Grape	Thrifty	.160	.030	.006	.196	25,640	4,760	960	31,360

Alkali in Vineyard Soil—Continued.

Grapevines.	Condition	Per Cent in Soil.				Pounds per Acre; 4 ft. depth.			
		Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda).	Chlorid (Common Salt)	Total Salts
Mission Grape	Not growing	.416	.010	.006	.432	66,520	1,560	920	69,000
Trousseau	Thrifty	.170	.007	.019	.196	27,200	1,120	3,040	31,360
Verdal	Thrifty	.160	.003	.023	.186	25,600	480	3,680	29,760
Teinturier mâle	Thrifty	.150	.003	.029	.182	24,000	480	4,640	29,120
Thompson's Seedless	Thrifty	.134	.003	.013	.150	21,480	520	2,040	24,040
Burger	Thrifty	.120	.005	.090	.215	19,200	800	1,440	21,440
Meunier	Thrifty	.094	.010	.006	.110	15,040	1,600	960	17,600
Meunier	Suffered	.209	.007	.012	.228	33,440	1,120	1,920	36,480
Meunier	Died	.207	.007	.018	.232	33,120	1,120	2,880	37,120
Flame Tokay	Thrifty	.070	.045	.004	.119	11,200	5,560	600	17,360
Flame Tokay	Not growing	.116	.031	.005	.152	18,560	4,960	800	24,320
Pedro Jimenes	Thrifty	.067	.023	.004	.094	10,680	3,600	600	14,880
Pedro Jimenes	Not growing	.110	.029	.006	.145	17,600	4,640	960	23,200
Negro	Thrifty	.081	.012	---	.093	12,960	1,920	---	14,880
Negro	Not growing	.206	.022	.005	.233	33,000	3,480	800	37,280

Of the above fourteen varieties of grapes the Persian withstands the effects of alkali the best, especially of carbonate of soda and common salt. There seems but little doubt that it would flourish in soils containing one tenth of one per cent of common salt, or an equivalent of 16,000 pounds per acre in four feet. The tolerance for carbonate of soda is great, for in the presence of more than two tenths of one per cent, or 25,600 pounds per acre, it managed to keep alive, thus indicating a true tolerance of probably 15,000 or perhaps 20,000 pounds per acre in four feet.

For other varieties the limits vary greatly, some being more sensitive to the several salts than others. The Sauvignon vert and Chasselas appear to be more tolerant of glauber salt and common salt than were other varieties, for they made a fine growth in the presence of about 40,000 pounds of sulfate and 5,000 pounds of common salt per acre in four feet. The Teinturier mâle would probably be their equal, for its amount of common salt was nearly the same.

The amount of carbonate of soda (black alkali) which the grape is able to withstand was in a few cases fairly well shown, especially where the common salt was low. Thus the Flame Tokay grew well in soil with 5,500 pounds of carbonate, and the Mission in presence of 4,700 pounds. Unfortunately the sulfate of soda is also very largely present and influences the results; thus the Flame Tokay was clearly killed by the 18,560 pounds of sulfate in conjunction with a large amount of carbonate. And yet a number of other varieties easily grow in twice this amount of sulfate.

The Meunier is very sensitive to alkali salts and succumbed to small amounts of carbonate and common salt combined with 33,000 pounds of sulfate, which was less than that in which many other varieties grew well. As a rule, grapevines seem to easily withstand 30,000 pounds of sulfate, and 5,000 of carbonate and common salt each.

NOTE ON THE EFFECT OF ALKALI SALTS UPON THE GROWTH OF GRAPEVINES AND ON THE COMPOSITION OF GRAPES.

By A. M. DAL PIAZ.

The injurious effect of strong alkali salts upon fruits in general is well known; grapevines are no exception, for strong alkali will kill them and weaker alkali affects them proportional to its strength and composition. The effect of alkali upon the vine and its product is a matter of economic interest, and an investigation on this subject was begun by the writer upon vines at the Tulare substation in 1900, and the results are here briefly presented; analyses of the alkali soils in which the vines were growing were made in the station laboratory by Mr. Snow.

The vines of the Burger, Sauvignon vert, and Trousseau were growing partly in weak and partly in strong alkali soils. The grapes of each variety did not show any marked difference in size, excepting where growing in strong alkali; but the vines themselves were there considerably shorter in growth, and therefore the bunches and berries were smaller and more advanced in maturity.

The Meunier is growing about an alkali spot, partly on weak alkali and showing a healthy growth, partly on stronger alkali and showing a shorter growth, and were killed on still stronger alkali. The following table gives the composition of these alkali soils, to which is added the results of examination of the sugar, acid, ash, and tannin in the grapes grown respectively on the weak and the strong alkali:

Pounds of Alkali Salts per Acre in Four Feet Depth.

	Sauvignon Vert.		Burger.		Trousseau.		Meunier.		
	Weak Alkali.	Strong Alkali.	Weak Alkali.	Strong Alkali.	Weak Alkali.	Strong Alkali.	Weak Alkali.	Strong Alkali.	Strong Alkali.
Sulfates	21,760	40,800	19,200	21,280	20,480	27,200	15,040	33,440	33,120
Carbonate	1,280	480	800	640	480	1,120	1,600	1,120	1,120
Chlorid	4,480	4,480	1,440	1,440	4,000	3,040	960	1,920	2,880
Total	25,520	45,760	21,440	23,360	24,960	31,360	17,600	36,480	37,120

Composition of Grapes: August 24, 1900.

Sugar %	26.39	24.43	20.24	20.60	25.75	24.64	26.86	24.53	
Acid %	.38	.65	.71	.59	.47	.50	.45	.50	Vines killed.
Ash %	.28	.37	.33	.33	.49	.36	.36	.40	
Tannin %	----	----	----	----	.147	.155	.159	.167	

The four grape varieties of the above table, grown on weak and strong alkali soils, show differences in growth and grape composition remarkably well. The sugar content seems to have throughout the tendency of decreasing with increasing strength of the alkali salts; this is shown by the varieties of Sauvignon vert, Trousseau, and Meunier. The Burger does not show this, because of the nearly equal strength of alkali in both soils.

The total acidity of the grapes seems to be less influenced by variations in strength of alkali; three of the varieties show an increase with increased alkali. This increase of total acidity and decrease of sugar content in strong alkali soils is doubtless caused by the diminished vigor and poor growth of the vines in such soils.

The analysis of the red wine varieties, Trousseau and Meunier, indicates a slight rise of tannin with increasing strength of alkali in the soils; this increase is, however, too small for drawing any final conclusions.

The above results seem to indicate some important facts worthy of being made known. First of all, the quality of wine grapes of the Tulare region does not decrease with increasing strength of alkali in the soil, at least up to a certain limit of total salts. The increase of total acidity of the grapes grown in stronger alkali is of special value in the making of sound wines in similar localities, while the decrease of sugar content secures at the same time a wine not too alcoholic. The practical wine-making experiments with Tulare grapes, undertaken by the Agricultural Experiment Station, have indicated this fact: they have shown that sound, light table-wines, excellent for blending purposes, or as light neutral wines for consumption, could be made of grapes grown on such alkali soils.

The growing of raisin grapes in strong alkali soils cannot be recommended, as the tendency of the sugar content to decrease with increasing alkali results in the production of an inferior raisin.

GRAIN.

Observations have been made for a number of years on the grains of the experiment station at Tulare, and it has been proven that they will grow in alkali soils where there is an absence of so much carbonate of soda as would corrode the tender crowns of the roots. Some of the results were published in the Report for 1894–5, and are included in the table below:

Alkali Salts in Grain Lands.

	Condition.	Per Cent in Soil.				Pounds per Acre; 4 ft. depth.			
		Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda)	Chlorid (Common Salt)	Total Salts
WHEAT—									
Tulare—Russian, Plot 12	3 feet high	.064	.006	.007	.077	10,240	1,000	1,120	12,360
	20 in. high	.095	.009	.004	.108	15,120	1,480	680	17,280
	6 in. high	.213	.023	.017	.253	34,120	3,640	2,680	40,440
Plot 16	Good	.089	.005	.007	.101	14,160	720	1,160	16,040
	Medium	.126	.001	.025	.152	20,120	200	3,920	24,240
	Very poor	.289	.002	.054	.345	46,160	360	8,680	55,200
Armona	Dead	.144	.026	.034	.204	23,040	4,180	5,360	32,580
GLUTEN WHEAT—									
Tulare	4 feet high	.027	.019	.001	.047	4,240	3,000	200	7,440
	Good	.131	.012	.009	.152	20,960	1,880	1,480	24,320
BARLEY—									
Tulare	4 feet high	.063	.074	.015	.152	10,720	12,170	2,630	25,520
Tulare	Yield 1 ton	.150	.028	.064	.242	12,020	2,200	5,100	19,320
Tulare	Dead	.061	.117	.020	.198	9,760	18,720	3,200	31,680
Hynes	Dead	.076	.020	.056	.152	12,160	3,200	8,960	24,320
RYE—									
Tulare		.061	.006	.011	.078	9,800	960	1,720	12,480

Wheat.—The Russian wheats, received from the U. S. Department of Agriculture, were planted in plot 12 of the Tulare substation. The rows extended across an alkali spot and presented heights corresponding to the strength of alkali; that in the soil of strongest alkali being about six inches, that at the end of the rows where alkali was weak having a height of several feet. Samples of soil were taken at the two extremes and at a medium point, as shown in the table above. The gradation in size seems to follow a similar gradation in amount of carbonate of soda, in inverse order, the smaller the carbonate the higher the stalk of wheat, 1,480 pounds being about the limit of tolerance. The amount of common salt was rather small to influence the results with the Russian wheats, but on plot 16 with other varieties it seemed to be the chief agent, the grain suffering more and more as the salt increased, a medium height occurring where there was 3,920 pounds per acre in four feet depth. The plot on which this wheat was planted is quite sandy and deep, with a thin incrustation of alkali on the surface, especially where the grain was poorest.

On plot 16, and in fact on all of the northwest corner of the station which is given to wheat, the ground was covered with a thick and white crust of alkali salts, even where the grain was several feet in height. The soil here is more of a loamy nature than that of plot 12, and was once a black alkali spot utterly bare of vegetation, but has been reclaimed by applications of gypsum.

The sample from Armona, Kings County, is from land once included in Tulare Lake region, but long left dry by the drying-up of the lake. Here the wheat died in presence of 4,180 pounds of carbonate of soda and 5,360 pounds of common salt, each being above the probable limits of tolerance.

From the results thus far obtained we would judge that wheat should do well in deep and loose soils having not more than 20,000 pounds of total alkali, of which there is not more than 1,200 pounds each of carbonate of soda and common salt per acre in four feet depth.

Alfalfa. Gluten Wheat. Goat's Rue.

PLATE 7. GRAIN AND FODDER PLANTS; TULARE SUBSTATION.

Gluten Wheat.—Gluten wheat at Tulare attained a splendid growth in presence of 24,300 pounds of alkali, of which nearly 1,500 pounds was common salt. In another spot, as shown in the photograph (plate 7), it also grew well in as much as 3,000 pounds of carbonate of soda per acre in four feet depth.

Barley.—The fact is shown in the table that barley grew to a height of four feet in land containing more than 12,000 pounds of carbonate of soda per acre in four feet, and produced one ton of hay per acre in presence of more than 5,000 pounds of common salt. It is therefore better adapted to alkali land than is wheat. It was killed by 18,720 pounds

of carbonate of soda, as would happen with most plants. At Hynes, in Los Angeles County, it was killed by 8,960 pounds of common salt, 3,000 of which was in the upper six inches.

Rye.—A fair test has not been given to rye as to its capabilities of withstanding alkali salts, for the amount found in the soil in which it was growing at the Tulare substation was very small.

LEGUMES AND FODDER PLANTS.

Special efforts have been made to obtain samples of soil from where these plants were growing well in strongest alkali and where they were severely affected by it, but we have been only partially successful. The Tulare substation has naturally furnished most of them, and further experiments and planting of those cultures which do not appear in the table will have to be made.

Alkali in Soils of Forage Crops.

	Per Cent in Soil.				Pounds per Acre: 4 ft. depth.			
	Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda)	Chlorid (Common Salt)	Total Salts
ALFALFA (young)—								
Tulare, 1 mi. N.E. Good—1st foot	.077	.006	------	.083	3,080	240	-------	3,320
2d foot	.060	.004	.010	.074	2,400	160	400	2,960
Total in 4 feet	.059	.008	.004	.071	9,440	1,280	680	11,400
1 mi. S.W. Dead—1st foot	.145	.016	.010	.171	5,800	640	400	6,840
2d foot	.103	.010	.010	.123	4,120	400	400	4,920
Total in 4 feet	.077	.011	.007	.095	12,280	1,680	1,080	15,040
1 mi. S.E. Dead—1st foot	.230	------	.026	.256	9,200	---- ---	1,040	10,240
2d foot	.084	------	.014	.098	3,360	--------	560	3,920
Total in 4 feet	.101	------	.013	.114	16,160	--------	2,080	18,240
Chino—Good—1st foot	.104	.051	------	.155	4,160	2,040	-------	6,200
2d foot	.071	.008	.005	.084	2,960	320	200	3,480
Total in 2 feet	.088	.030	.003	.121	7,000	2,360	200	9,560
Fair—1st foot	.241	.014	.019	.274	9,640	560	760	10,960
2d foot	.037	.017	------	.054	1,480	680	--------	2,160
Total in 2 feet	.139	.016	.010	.165	11,120	1,240	760	13,120
Killed ------1st foot	.289	.022	.009	.320	11,560	880	360	12,800
2d foot	.023	.022	.005	.050	920	880	200	2,000
Total in 2 feet	.156	.022	.007	.185	12,480	1,760	560	14,800
ALFALFA (4 years old)—								
Yuma—Splendid—4 feet	.462	.009	.027	.498	73,960	1,400	4,400	79,760
6 feet	.427	.009	.024	.460	102,480	2,080	5,760	110,320
TURKESTAN ALFALFA—Good	.023	.014	.007	.044	3,680	2,240	1,120	7,040
LUPIN, EUROPEAN—Good	.034	.017	.019	.070	5,440	2,720	3,040	11,200
Medium	.168	.009	.047	.224	26,880	1,440	7,520	35,840
Failure	.250	.004	.038	.292	40,000	640	6,080	46,720

Alkali in Soils of Forage Crops—Continued.

	Per Cent in Soil.				Pounds per Acre; 4 ft. depth.			
	Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda)	Chlorid (Common Salt)	Total Salts
HAIRY VETCH—								
Plot 8—Fair 1st foot	.621	.014	.045	.680	24,840	560	1,800	27,200
2d foot	.616	.027	.011	.654	24,640	1,080	440	26,160
Total in 4 feet	.398	.016	.020	.434	63,720	2,480	3,160	69,360
Plot 12—Good 1st foot	.458	.003	.009	.470	18,320	120	360	18,800
2d foot	.162	.010	.014	.186	6,480	400	560	7,440
Total in 4 feet	.180	.010	.008	.198	28,840	1,640	1,280	31,760
Very poor 1st foot	1.178	.018	.138	1.334	47,120	720	5,520	53,360
2d foot	.220	.024	.032	.276	8,800	960	1,280	11,040
Total in 4 feet	.395	.025	.047	.467	63,120	3,960	7,480	74,560
BUR CLOVER—Good	.057	.113	------	.170	5,700	11,300	--------	17,000
WHITE MELILOT—Good	.031	.003	.003	.037	4,920	480	440	5,840
GOAT'S RUE—Splendid	.068	.005	.001	.074	10,880	760	160	11,800
SORGHUM—Splendid	.387	.062	.061	.510	61,840	9,840	9,680	81,360
MODIOLA—Splendid 1st foot	.170	.119	1.021	1.310	6,800	4,760	40,860	52,420
JERSEY KALE—Plot 8 1st foot	.854	.013	.009	.876	34,160	520	360	35,040
2d foot	.285	.009	.056	.350	11,400	360	2,240	14,000
Total in 4 feet	.322	.023	.019	.364	51,480	3,600	3,000	58,080
ESSEX RAPE—Plot 8 1st foot	1.141	.011	.014	1.166	45,640	440	560	46,640
2d foot	.232	.023	.037	.292	9,280	920	1,480	11,680
Total in 4 feet	.391	.034	.015	.440	62,560	5,480	2,440	70,480
SALTBUSHES—								
Atriplex semibaccata	.785	.116	.078	.979	125,640	18,560	12,520	156,720
Atriplex pamparum	.047	.091	------	.138	7,560	14,600	--------	22,240

Alfalfa.—As this is the most important of the fodder plants of the State, we have made special efforts to ascertain the limits of tolerance of the various salts of alkali, but have been largely disappointed, because of the fact that the amount varies according to the stage of growth of the plant. When young its roots are very tender and sensitive to the corrosive action of carbonate of soda, and being confined to the upper foot or two of the soil are fully within its reach. But when the roots are older and have penetrated deeply into the soil, the root-crown has become more corky and hardened and less sensitive, so that they are enabled to withstand a far larger amount of the alkali.

These facts are clearly shown in the results given in the table. From the country around Tulare Mr. Forrer, the foreman of the substation, obtained many samples of soil from alfalfa fields where the plant was growing and where it had died. The maximum amount of total alkali found to a depth of four feet where the plant was growing well was 11,360 pounds, in which there was very little common salt and 1,300

pounds of carbonate of soda; while a short distance from this, where the plant had died, there was about the same amount of total alkali, but containing 1,100 pounds of common salt and 1,600 pounds of carbonate. In the first case the carbonate was chiefly in the lower third and fourth feet, while where the crop was dead the carbonate was chiefly in the upper two feet.

At the substation farm near Chino the results were very similar; alfalfa made a fair growth in the presence of 1,240 pounds of carbonate, and was killed by 1,760 pounds in the upper two feet, the common salt being low and the sulfate high in both cases. It is also very worthy of note that on the same plot the plant grew splendidly with a larger amount of carbonate of soda (2,360 pounds), because nearly all of the salt was held in the upper foot of soil and hence probably above the feeding roots. There was only a trace of common salt here, and but little in the second foot.

The tolerance of young alfalfa may then be placed at about 1,200 pounds of carbonate of soda, 750 pounds of common salt, and 12,000 pounds of sulfate per acre in the upper two feet of soil. But when the plant is older and its roots become firmly fixed in the soil, penetrating it deeply and spreading out laterally, the limits of toleration far exceed the above figures, even to an extent almost beyond belief. This is largely due to the perfect shading of the ground, thereby preventing the rise of the alkali.

In the neighborhood of Yuma, alfalfa fields were seen by Mr. F. J. Snow (student assistant in the laboratory) to be strongly charged with alkali and yet to be in fine condition. He was told that four years were required in getting a full stand, but after that the plant grew luxuriantly, yielding seven cuttings per year. The amount and character of the salts in the soil are given in the table. From another field where the alfalfa was also growing luxuriantly Mr. Snow found similar amounts of alkali of quite nearly the composition given above, except that the total in the first foot was nearly 17,000 pounds (.424 per cent) instead of 15,000.

The plot of alfalfa growing near the gluten wheat at the Tulare substation, shown in the photograph (plate 7), left side, is on a soil containing 3,440 pounds of carbonate of soda; but this salt is chiefly held below the upper two feet of soil, thus giving the feeding roots freedom from its action. The rise of the alkali is prevented from evaporation by the dense shading of the foliage.

Professor Buffum, of the Wyoming Experiment Station, has found that alfalfa was killed in a total of .706 per cent of alkali in the surface foot, all except .041 per cent of chlorid being sulfates of soda and magnesia. This would be equivalent to 28,240 pounds of total alkali per acre-foot and 1,640 pounds of chlorid. He also found that it grew

in .152 per cent of alkali in the surface foot, equivalent to 6,080 pounds per acre; but this is more than doubled in the Yuma soil, as shown in the table.

While, therefore, alfalfa is easily killed by alkali when young, it will tolerate as much as 6,000 pounds of common salt, 3,000 pounds of carbonate, and 102,000 pounds of sulfate in six feet per acre if it succeeds in getting a good start and in sending its roots below the surface of the soil; and especially if the greater part of the alkali be sulfates. It is therefore very essential that prior to sowing alfalfa the alkali salts should be leached downward from the surface by thorough irrigation, until the plant is old enough to resist their attack by the hardening of its root-crown.

The importance of thoroughly washing the alkali deeply into the soil before the seed is planted, and keeping it there by proper means until the foliage of the plant shades the soil sufficiently to prevent the rise of moisture and alkali, is well illustrated in fields in the region of Bakersfield, where alfalfa is now growing in soils once heavily charged with alkali. From one of these fields samples of soil were taken by us where the alkali was supposed to be strongest beneath the alfalfa, and also from an adjoining untreated alkali spot which was said to represent conditions before alfalfa was planted. The results are given in pounds per acre in four feet depth.

	Sulfates.	Carbonate.	Common Salt.	Total Alkali.
Alkali spot before alfalfa was planted	60,120	720	175,840	236,680
Alfalfa field; alkali washed down	14,400	---	1,040	18,640

In the natural alkali soil the salts are distributed downward, somewhat evenly, except that there are in the surface foot nearly 140,000 pounds of common salt, while in the alfalfa field the alkali salts are chiefly below the second foot. A closer examination would doubtless have shown the main body of alkali to have been washed down to six feet from the surface, or even deeper.

Too much emphasis cannot, therefore, be placed upon the importance of thus controlling alkali and keeping it below a depth of four or five feet.

Blue European Lupin.—The plot in which the lupins were grown has the greater part of its alkali within the upper two feet, while in that part where the lupins failed three-fourths of the common salt and the sulfates was held in the first foot itself. Both the common salt and sulfates seem to be responsible for the failure of the lupins, and it is clear that it cannot withstand more than 3,000 pounds of the former per

acre; of the carbonate of soda it will tolerate as much as and perhaps more than 3,000 pounds per acre.

Hairy Vetch.—This fodder and green-manuring plant grew fairly well, reaching a height of about fourteen inches and bloomed in land containing 2,400 pounds of carbonate of soda, 3,000 pounds of common salt, and 63,700 pounds of sulfate per acre in four feet depth. As with the lupins and the vegetables, we find that here, too, the alkali occurs chiefly in the upper two feet of the soil, the common salt especially being in the first foot.

The very large amount of sulfates tolerated would show that when black alkali lands are neutralized with gypsum, the vetch will do fairly well, provided that common salt is not excessive. The limit of tolerance of the latter is a matter of doubt, for in the soil in which the vetch had a poor growth, there was present about 4,000 pounds of carbonate in addition to the 7,500 pounds of chlorid, and to either of these salts may have been due the bad effect. But in both of the soils examined the carbonate was chiefly in the second and third feet, and as its action is chiefly upon the tender root-crown at the surface of the soil, it would seem that the common salt was responsible for poor growth.

The foreman of the substation says that when young the vetch has a tendency to lie flat on the ground, so that on alkali soil it "burns" badly.

Bur Clover.—This clover was found growing luxuriantly in a small field adjoining the hot sulphur baths at Elsinore, in Riverside County. The soil received its water from a deep well, and was black from humus dissolved in the carbonate of soda of the alkali. An examination of the soil to thirty inches depth showed the remarkable toleration of 11,300 pounds of carbonate of soda per acre, thus giving it the rank of second in this regard among all the cultures examined. It doubtless is fully as tolerant as barley, which, aside from sorghum, heads the tolerance list of grasses thus far.

Argentine Saltbush (*Atriplex pamparum*).—The Inspector of Stations says of this saltbush: "*Atriplex pamparum* was sent to the Station by President Rocca of the Argentine Republic in 1897, together with seeds of other species of native saltbushes recommended to him by the botanists of that country. It has thus far proved to be the best species at Tulare substation, growing in alkali soil to a height of six feet and spreading fourteen feet in diameter. It is a browsing plant and is much liked by sheep. If kept down by feeding it furnishes much succulent food and is worth extensive trial." The examination of the soil where it grows luxuriantly shows the presence of 14,600 pounds of carbonate of soda, an amount nearly equal to that tolerated by the Australian saltbush.

Australian Saltbush (*Atriplex semibaccata*).—After a number of efforts we have finally found this fodder plant growing well in very strong alkali land, in which the several salts were in greatest amount within two feet of the surface. As it ranks high as a fodder plant suitable for alkali soils, we give the distribution of the salts in the soil-column:

Alkali Soil Growing Australian Saltbush.

	Per Cent in Soil.				Pounds per Acre.			
	Sulfates	Carbonate	Chlorid	Total	Sulfates	Carbonate	Common Salt	Total
First foot	2.055	.284	.121	2.460	82,200	11,360	4,840	98,400
Second foot	.634	.089	.111	.834	25,360	3,560	4,440	33,360
Third foot	.247	.042	.051	.340	9,880	1,680	2,040	13,600
Fourth foot	.205	.049	.030	.284	8,200	1,960	1,200	11,360
Total	3.141	.464	.313	3.918	125,640	18,560	12,520	156,720

These figures doubtless very nearly represent the maximum tolerance of the saltbush.

Very young plants have, however, suffered or languished in surface soils containing 9,000 pounds of carbonate of soda and 11,000 pounds of common salt, or a total of 31,000 pounds of alkali salts per acre; and have died when the soil was covered with an alkali crust containing 4.0 per cent of carbonate and 6.0 per cent of common salt. The plant came up easily from the seed in a soil containing 5,000 pounds of carbonate and 3,000 pounds of common salt per acre.

Sorghum.—At the Tulare substation sorghum grows luxuriantly in a small tract having a large amount of alkali, the surface often being black from humus held by the carbonate of soda. Irrigation is used on the crop, and there is therefore more alkali at the surface than at the third and fourth feet, although the dense mass of the crop shades the soil quite effectually. An examination of the soil shows a higher amount of alkali salts than in the soil of any other small culture thus far examined, viz.: 81,440 pounds per acre in four feet depth. The table of analyses shows that sorghum can easily tolerate as much as 10,000 pounds of carbonate of soda, the same of common salt, and 75,000 pounds of glauber salt per acre in four feet. At the time the examination was made, one half of the total glauber salt was in the upper foot, the

greater part of the carbonate was in the second and third feet, while the common salt was quite evenly distributed through the four feet.

White Melilot.—Plants of this forage crop were found growing well near the "sump" in what was supposed to be very strong alkali, for the surface of the soil was crusted with it. But results of the examination show that there was less than 6,000 pounds of the salts per acre in four feet.

Goat's Rue (*Galega officinalis*).—A large patch of this was growing on plot 12 by the side of alfalfa and gluten wheat, and each of the three cultures were in splendid condition, the Goat's Rue being in dense mass and full growth, as shown on the right side of the photograph on page 26. Carbonate of soda and common salt were present in the soil in very small amounts, while of the sulfate there was nearly 11,000 pounds. The soil is sandy, and this amount is not excessive. The plant reached a height of about three and a half feet, and three cuttings were obtained.

Jersey Kale and Essex Rape.—These crops in the vegetable plot of the Tulare substation made a splendid start in strong alkali soil, preserving a dense growth, full of life and vigor. But each after reaching fourteen inches in height succumbed to the dryness and heat of the summer.

Modiola.—No further observations have been made on this forage plant than those given in the Report for 1896. It was grown by Mr. Leckenby near Bakersfield in soil containing more than 40,000 pounds of common salt and about 5,000 pounds of carbonate of soda per acre, in the surface foot. It is chiefly suited for permanent pasture, being of low growth and rooted at joints, so that it is not readily cut.

VEGETABLES AND GRASSES.

The vegetable plot 8 is located upon a strong alkali spot by the side of the main avenue of the station along whose side Australian saltbush grows luxuriantly. The alkali in this plot is of varying strength, being strongest along the roadside, where we usually find either failures or very weak vegetable plants. A general view of the plot with the cultures as seen in April, 1901, is given in the accompanying photograph (plate 8); a portion of the orchard, and long lines of saltbush are also seen on the left.

The alkali salts are mostly concentrated in the upper two feet of the soil, and their action is therefore more energetic than if distributed throughout four feet depth.

Alkali in Soils of Vegetables.

	Per Cent in Soil.				Pounds per Acre.			
	Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda).	Chlorid (Common Salt)	Total Alkali
SUGAR BEETS—Fair.								
Tulare, Plot 8 ....1st foot	.541	.008	.009	.558	21,640	320	360	22,320
2d foot	.381	.006	.075	.462	15,240	240	3,000	18,480
Total in 4 feet	.329	.011	.034	.374	52,640	1,760	5,440	59,840
Plot 12 ....1st foot	.725	.003	.028	.756	29,000	120	1,120	30,240
2d foot	.337	.042	.009	.388	13,480	1,680	360	15,520
Total in 4 feet	.304	.025	.012	.341	48,560	4,000	1,920	54,480
CARROTS—Fair.								
Tulare, Plot 8 ....1st foot	.357	.014	.023	.394	14,280	560	920	15,760
2d foot	.088	.010	.016	.114	3,520	400	640	4,560
Total in 4 feet	.156	.008	.015	.179	24,880	1,240	2,360	28,480
RADISHES—In flower.								
Tulare, Plot 8 ....1st foot	1.012	.024	.047	1.083	40,480	960	1,880	43,320
2d foot	.137	.092	.009	.238	5,480	3,680	360	9,520
Total in 4 feet	.324	.055	.014	.393	51,880	8,720	2,240	62,840
CELERY—								
Santa Ana—Good	.340	.....	.080	.420	4,080	.....	9,600	13,680
Failure	1.027	.....	.276	1.303	123,240	.....	33,120	156,360
ARTICHOKES—Fair.								
Tulare, Plot 8 ....1st foot	.563	.010	.005	.578	22,520	400	200	23,120
2d foot	.234	.017	.009	.260	9,360	680	360	10,400
Total in 4 feet	.242	.017	.009	.268	38,720	2,760	1,480	42,960
SPINACH AND ENGLISH BROAD BEANS—Failures.								
Tulare, Plot 8 ....1st foot	.832	.002	.195	1.029	33,280	80	7,800	41,160
2d foot	.163	.033	.030	.226	6,520	1,320	1,200	9,040
Total in 4 feet	.335	.012	.061	.408	53,600	1,920	9,760	65,280
ELEUSINE CORACANA—Failure.								
Tulare....1st foot	.812	.015	.019	.846	32,480	600	760	33,840
2d foot	.140	.046	.010	.196	5,600	1,840	400	7,840
Total in 4 feet	.255	024	.010	.289	40,720	3,800	1,560	46,080

Sugar Beets.—The sugar beets both on plot 8 and on plot 12 were planted close together, and were allowed to grow in that thick mass instead of being thinned-out to allow of development of root as when grown for their sugar content. The result was that while the tops were large and green, showing fair growth, the roots were about a foot in length with an average diameter of about an inch only. This small size may be largely attributed to the effect of the severe climate as well as to the crowding of the plants, for their leaves gave no indication of suffering from the alkali in the soil. The maximum of each salt tolerated by the plant in these two plots was 52,000 pounds of sulfates, 4,000 pounds of carbonate, and 5,400 pounds of common salt. The beets growing on plot 8 were very small, the largest weighing but about three ounces; a beet of that size should have a very high sugar content, but we find only 13.1 per cent and a purity coefficient of 80.

The largest beet on plot 12, in which there was less alkali than in

plot 8, weighed about seven and one-half ounces and had a sugar content of 16.1 per cent and a purity coefficient of 81.

Previous results, given in the Annual Report of this station for 1895–6, show that the presence of 3,600 pounds of common salt in the soil seriously affected the sugar content of the beet; the above results lower this amount to 1,900 pounds, and even this seems to be above the limit in which the beet can attain good size and fair sugar-percentage.

Carrots.—The test was made on plot 8, and in presence of a total of 28,000 pounds of alkali, of which 2,300 was common salt; the plant

PLATE 8. VEGETABLE PLOT 8, TULARE SUBSTATION.

1. Artichokes.
2. Carrots.
3. Radishes in bloom.
4. Essex Rape and Jersey Kale.
5. Sunflowers and Sugar Beets.

Australian Saltbush in rows on left.

grew well, the roots having a length of about 10 inches, but a diameter of only about three fourths of an inch; the Foreman of the station, however, says that they were tender and of good flavor.

Radishes.—At the Tulare substation radish seed was planted in what seems to have been the strongest alkali of plot 8, and yet the seed germinated and the plant reached maturity, being in flower at the time the photograph and soil samples were taken. While the carbonate of soda was present in very large amount (8,700 pounds), it was chiefly held below the upper foot of the soil and therefore had no effect on the

seed and young plant. Common salt was, on the contrary, chiefly in the upper foot, as was also the sulfate of soda. The radish, therefore, is capable of withstanding quite a large amount of alkali, if the carbonate is below the upper foot.

Globe Artichokes.—The amount of alkali in the soil where the artichokes were growing was about 43,000 pounds per acre, the sulfates being largely in the upper two feet, while more than half of the carbonate of soda and common salt respectively was below that depth.

Spinach and English Broad Bean.—These vegetables were grown on very strong alkali soils and were almost complete failures. A few scattering plants appeared where the carbonate of soda was only 2,000 pounds per acre and chiefly below the first foot, but they reached a height of only a few inches. The amount of common salt was about 9,000 pounds per acre.

Spelt and *Eleusine coracana* were both complete failures in the presence of 40,000 pounds of alkali.

The *Celery* fields in the alluvial lands around Santa Ana furnish good examples of the effects of alkali salts, except that no carbonate of soda was found in the samples kindly sent by Mr. Cole from spots where the plant was growing well and where the plant died. The results show that celery will easily tolerate as much as 10,000 pounds of common salt per acre, but is killed by 30,000 pounds.

Onions have grown well from the seed in the black alluvial soil of Leonis Valley, Mojave Plateau, Los Angeles County, which contained in the surface foot 400 pounds of common salt and 4,000 pounds of sulfate per acre.

Potatoes.—In the black alluvial soil of the Kern River near Bakersfield, which held in the first foot 18,400 pounds of alkali per acre, of which 4,000 was carbonate of soda and 6,800 common salt, two crops of potatoes were raised in a season, but their keeping quality was very poor. (Report 1896.)

GRASSES.

Ray grass at the Tulare substation grew well in a soil containing about 7,000 pounds of alkali per acre, which held no carbonate and very little common salt.

No observations on the tolerance of alkali on the part of grasses, and of crops not given above, that would increase the figures there shown, or which would throw more light on the subject, have been made since those published in the Report of 1896. These results show the amounts in the surface foot alone instead of in four feet depth; but at Chino,

where the observations were made, the bulk of the salts is within the first foot.

Summarizing the data there given we have the following groupings of maximum amounts in the surface foot per acre in which the true grasses have thus far been found to do well:

Grasses Growing in Alkali Soils. Depth one foot.

CARBONATE OF SODA.

3,300 lbs. per acre: Japanese Wheat Grass, Barley.
2,500 to 3,000 lbs. per acre: Awnless Brome Grass, Schrader's Brome Grass, Sheep Fescue, Tall Fescue.
2,000 to 2,500 lbs. per acre: Egyptian Millet, Hard Fescue, Many-Flowered Paspalum, English Ray Grass, Rough-Stalked Meadow and Orchard Grass.
1,000 to 2,000 lbs. per acre: Bearded Darnel, Blue Grass.
600 to 1,000 lbs. per acre: Meadow Fescue, Many-Flowered Millet, Meadow Soft Grass, Italian Ray Grass.

COMMON SALT.

7,040 lbs. per acre: Barley.
3,000 lbs. per acre: Japanese Wheat Grass.
1,500 lbs. per acre: Schrader's Brome Grass.
900 lbs. per acre: Awnless Brome Grass, Sheep Fescue, Tall Fescue.
250 to 500 lbs. per acre: Many-Flowered Millet, Italian Ray Grass, English Ray Grass, Bearded Darnel, Orchard Grass.

MISCELLANEOUS.

There are a number of trees and other cultures growing upon the alkali soils of the Tulare substation that are of general interest, though in some cases the amount of alkali in their soils is low.

Miscellaneous Cultures and Trees.

Tulare Substation.	Condition.	Per Cent in Soil.				Pounds per Acre; 4 ft. depth.			
		Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda).	Chlorid (Common Salt)	Total Alkali
Russian Sunflower, 1900	Good	.156	.008	.015	.179	24,880	1,240	2,360	28,480
Russian Sunflower, 1901	Good	.329	.011	.034	.374	52,640	1,760	5,440	59,840
Russian Sunflower	Poor	.226	.020	.010	.256	36,120	3,160	1,560	40,840
Washingtonia Palm	Large	.032	---	.006	.038	5,080	-----	1,000	6,080
Washingtonia Palm	Small	.082	.008	.007	.097	13,040	1,200	1,040	15,280
Date Palm	Large	.045	.018	---	.063	5,520	2,800	-----	8,320
Camphor Tree	Large	.033	.002	.009	.044	5,280	320	1,420	7,020
Oriental Sycamore	Large	.120	.020	.127	.267	19,240	3,200	20,320	42,760
Eucalyptus amygdalina	Large	.217	.017	.019	.253	34,720	2,720	2,960	40,400
Kölreuteria	Fair	.319	.062	.079	.460	51,040	9,920	12,640	73,600
Cañaigre	Fair	.057	.001	----	.058	9,160	120	80	9,360

Russian Sunflower.—The sunflower on plot 8 of the Tulare substation grew to a height of three feet and matured its seed in presence of about 60,000 pounds of alkali salts; the amount of carbonate of soda was,

however, rather low, while that of common salt was high (5,440 pounds). When, however, the carbonate was increased to a little more than 3,000 pounds per acre in four feet depth, the plants were severely affected, their average height being only fourteen inches.

Washingtonia Palm.—A number of these palms are growing along the border of the station tract and county road, in soils containing about 15,000 pounds of alkali salts per acre. The palms look well, though differing in height, and none of them seem to have been affected by alkali.

Date Palm.—A large date palm is growing in a sandy alkali soil at the Tulare substation and is not at all affected by the two hundredths of one per cent of carbonate of soda present. It will clearly tolerate a larger amount. Only a trace of common salt was found in the soil.

Camphor Tree.—The tree is in splendid condition, having a height of fifteen feet and spreading strongly and with good foliage. The alkali is too small in amount to affect it.

Oriental Sycamore.—The carbonate of soda around the roots of this large tree is comparatively small (3,200 pounds), but common salt is present to the extent of more than one tenth of one per cent, which gives the enormous amount of 20,000 pounds per acre in four feet depth. It is clear, then, that in almost any alkali land reclaimed from carbonate of soda this tree will make good growth.

Eucalyptus amygdalina.—This tree is growing well in even stronger alkali land than the sycamore, its tolerance of common salt being more than 20,000 pounds per acre. The amount of carbonate of soda which it will withstand has not yet been ascertained, as there was but 1,900 pounds present here.

Kölreuteria paniculata.—This small tree was found growing in the alkali sump which had received much of the alkali drainage of the station tract, and where the alkali was supposed to be strongest. The amount of carbonate of soda was found to be greater than elsewhere, nearly 10,000 pounds per acre in four feet; but the common salt was less than found in the soil of the eucalyptus tree.

GENERAL SUMMARY OF RESULTS THUS FAR OBTAINED.

The following tables present in brief form for comparisons the nearest approach to maximum tolerance of each of the salts of alkali thus far obtained for fruits and other cultures; giving, of course, the amounts in which each culture was growing and in good condition entirely unaffected by alkali. The cultures are arranged in the order of highest tolerance.

These results are of course only tentative, for in a great majority of cases future examinations will probably greatly raise the figures given in the tables.

Aided by the coöperation of the farmers throughout the State where alkali lands exist, this work will be continued, and we hope to greatly increase the value of the results obtained.

Highest Amount of Alkali in Which Fruit Trees Were Found Unaffected.

Arranged from highest to lowest. Pounds per acre in four feet depth.

Sulfates (Glauber Salt).		Carbonate (Sal Soda).		Chlorid (Common Salt).		Total Alkali.	
Grapes	40,800	Grapes	7,550	Grapes	9,640	Grapes	45,760
Olives	30,640	Oranges	3,840	Olives	6,640	Olives	40,160
Figs	24,480	Olives	2,880	Oranges	3,360	Almonds	26,560
Almonds	22,720	Pears	1,760	Almonds	2,400	Figs	26,400
Oranges	18,600	Almonds	1,440	Mulberry	2,240	Oranges	21,840
Pears	17,800	Prunes	1,360	Pears	1,360	Pears	20,920
Apples	14,240	Figs	1,120	Apples	1,240	Apples	16,120
Peaches	9,600	Peaches	680	Prunes	1,200	Prunes	11,800
Prunes	9,240	Apples	640	Peaches	1,000	Peaches	11,280
Apricots	8,640	Apricots	480	Apricots	960	Apricots	10,080
Lemons	4,480	Lemons	480	Lemons	800	Lemons	5,760
Mulberry	3,360	Mulberry	160	Figs	800	Mulberry	5,760
Other Trees.							
Kölreuteria	51,040	Kölreuteria	9,920	Or. Sycamore	20,320	Kölreuteria	73,600
Eucal. am.	34,720	Or. Sycamore	3,200	Kölreuteria	12,640	Or. Sycamore	42,760
Or. Sycamore	19,240	Date Palms	2,800	Eucal. am.	2,960	Eucal. am.	40,400
Wash. Palms	13,040	Eucal. am.	2,720	Camph. Tree	1,420	Wash. Palms	15,280
Date Palms	5,500	Wash. Palms	1,200	Wash. Palms	1,040	Date Palms	8,320
Camph. Tree	5,280	Camph. Tree	320			Camph. Tree	7,020
Small Cultures.							
Saltbush	125,640	Saltbush	18,560	Modiola	40,860	Saltbush	156,720
Alfalfa, old	102,480	Barley	12,170	Saltbush	12,520	Alfalfa, old	110,320
Alfalfa, young	11,120	Bur Clover	11,300	Sorghum	9,680	Alfalfa, young	13,120
Hairy Vetch	63,720	Sorghum	9,840	Celery	9,600	Sorghum	81,360
Sorghum	61,840	Radish	8,720	Alfalfa, old	5,760	Hairy Vetch	69,360
Sugar Beet	52,640	Modiola	4,760	Alfalfa, yo'ng	760	Radish	62,840
Sunflower	52,640	Sugar Beet	4,000	Sunflower	5,440	Sunflower	59,840
Radish	51,880	Gluten Wheat	3,000	Sugar Beet	5,440	Sugar Beet	59,840
Artichoke	38,720	Artichoke	2,760	Barley	5,100	Modiola	52,420
Carrot	24,880	Lupin	2,720	Hairy Vetch	3,160	Artichoke	42,960
Gluten Wheat	20,960	Hairy Vetch.	2,480	Lupin	3,040	Carrot	28,480
Wheat	15,120	Alfalfa	2,360	Carrot	2,360	Barley	25,520
Barley	12,020	Grasses	2,300	Radish	2,240	Gluten Wheat	24,320
Goat's Rue	10,880	Kaffir Corn	1,800	Rye	1,720	Wheat	17,280
Rye	9,800	Sweet Corn	1,800	Artichoke	1,480	Bur Clover	17,000
Cañaigre	9,160	Sunflower	1,760	Gluten Wheat	1,480	Celery	13,680
Ray Grass	6,920	Wheat	1,480	Wheat	1,160	Rye	12,480
Modiola	6,800	Carrot	1,240	Grasses	1,000	Goat's Rue	11,800
Bur Clover	5,700	Rye	960	White Melilot	440	Lupin	11,200
Lupin	5,440	Goat's Rue	760	Goat's Rue	160	Cañaigre	9,360
White Melilot	4,920	White Melilot	480	Cañaigre	80	Ray Grass	6,920
Celery	4,080	Cañaigre	120			White Melilot	5,840

Since the above was in type the following additional data regarding special cultures at the ten-acre tract of the Southern California substation have been obtained. The analyses of the soils of the several plots show an almost entire absence of common salt, and the cultures have therefore only to contend with carbonate of soda and the sulfates. The figures show the amount of alkali in three feet of soil per acre. The soil is a close-grained black loam, not sandy as at Tulare.

PLOT 8.

Sulfates, 9,880 lbs.; Carbonate, 2,360 lbs.; total, 12,320 lbs.
Cultures all killed by the alkali.

Safflower	Bearded Crowfoot Grass
Globe Artichoke	Celery
Sunflower	Dwarf Essex Rape
Esparto Grass	

PLOT 45.

Sulfates, 3,080 lbs.; Carbonate, 2,120 lbs.; total, 5,200 lbs.
Cultures all killed by alkali.

Fennel	Medicinal Rhubarb
Burdock	Quinoa
Caraway	Coriander
Calendula	

PLOT 34.

Sulfates, 1,880 lbs.; Carbonate, 1,560 lbs.; total, 3,440 lbs.
Cultures all killed by alkali.

Saltwort	Tall Oat Grass
Russian Millet	Perennial Ray Grass
Golden Millet	Roman Chamomile
Japanese Wheat Grass	German Chamomile

PLOT 19.

Sulfates, 1,520 lbs.; Carbonate, 1,440 lbs.; total, 2,960 lbs.
Cultures all killed by alkali.

Italian Ray Grass	French Lentil
Side Oats Grama	Dal
Herds Grass	Fenugreek
Crimson Clover	Kidney Vetch
Elusine Barcinonensis	Golden Thorpe Barley
Crested Koeleria Grass	German Millet

PLOT 43.

Sulfates, 1,920 lbs.; Carbonate, 1,800 lbs.; total, 3,720 lbs.
Cultures doing fairly well.

Broccoli	White Kaffir Corn
Chard	Red Kaffir Corn
Fennel	Sweet Corn
Dwarf Essex Rape	Teosinte
Black Rice Corn	

African (*A. halimus*) Saltbush did not germinate.

PLOT 63.

Sulfates, 1,080 lbs.; Carbonate, 1,320 lbs.; total, 2,400 lbs.
California Flax grew one foot in height and was heavy with seed.

CONCLUSIONS.

A review of the above tables and of the more detailed results brings with it the following conclusions:

1. While for the crops in general the maximum tolerance for alkali salts has not yet been definitely found, close approximations are reached with a number, such as the apple, peach, orange, and lemon trees, with respect to carbonate of soda and common salt. In one or two instances alone was the sulfate of soda the apparent cause of distress on the part of a tree.

2. Grapes and olives thus far stand at the head among fruits in their tolerance of each of the alkali salts; oranges grew in a larger amount of carbonate than did the olive, but that salt was chiefly held below the two surface feet. On the other hand, the lemon seems to be the most sensitive to the effects of alkali, especially to common salt, and next to it the orange.

3. The amount tolerated depends largely upon the distribution of the several salts in the vertical soil-column, the injury being most severe in the surface foot, where under the influence of the unfortunate practice of surface-irrigation the feeding rootlets are usually found. It is therefore important that in alkali regions such methods of culture and irrigation should be followed as to encourage deep rooting on the part of crops.

4. The amount tolerated varies with the variety of the same plant, as shown in the grape.

5. The amount of alkali tolerated by the various cultures varies with the nature of the soil. It is lowest in heavy clay soils and fine-grained soils, in which the downward movement of plant roots is restricted; and highest in loam and sandy soils, in which the roots have freedom of penetration.

6. Some plants, such as the saltbush and alfalfa, are quite susceptible to alkali salts when young, but when the roots penetrate deeply, and the ground is heavily covered with the foliage of the plant, they are immune to a very large extent.

7. Lands heavily charged with alkali may often be made productive for certain crops by the application of irrigation water in sufficient amount to leach the salts down to a depth of several (five or six) feet, and by preventing their subsequent rise by proper mulching, or cultivation until the foliage of the plant itself will prevent evaporation of the soil moisture from the surface of the ground. Alfalfa culture has thus been made highly profitable in lands once so strongly charged with alkali as to kill all vegetation.

8. The reclamation of lands charged with carbonate of soda by

neutralization with gypsum often renders possible the profitable planting of such crops as withstand large amounts of common salt or of glauber salt.

9. The effects of carbonate of soda are seen in the yellowing of the leaves of the tree caused by its corrosive action on the root-crown, whereby the proper flow of sap and food supply to the leaves is prevented. The effect of common salt is seen in the falling of the leaves from the newer branches, and in the blackening and curling of the leaves of pears, as shown in the photograph on the title-page of this bulletin.

10. Sulfate of soda (glauber salt) is hurtful only when present in very large amounts, most cultures doing well in more than 10,000 pounds per acre in four feet depth; saltbush, hairy vetch, alfalfa, and sorghum grew well in more than 61,000 pounds.

11. Barley is better adapted to alkali land than is wheat, for it will withstand the effects of twice the amount of carbonate of soda and common salt. Of course, the carbonate may be neutralized with gypsum, and in the absence of much common salt will permit of the growth of excellent crops of wheat; but where the amount of common salt exceeds 5,000 pounds barley should be given the preference over wheat.